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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

PERFORMANCE OF 19XB-2A GAS TURBINE

I - EFFECT OF PRESSURE RATIO AND INLET PRESSURE ON TURBINE PERFORMANCE FOR AN INLET TEMPERATURE OF 800° R

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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INTRODUCTION

An investigation of the 19XB-2A gas turbine is being conducted at the Cleveland laboratory to determine the effect on turbine performance of various inlet pressures, inlet temperatures, pressure ratios, and wheel speeds. The engine of which this turbine is a component is designed to operate at an air flow of 30 pounds per second at a compressor rotor speed of 17,000 rpm at sea-level conditions. At these conditions the total-pressure ratio is 2.08 across the turbine and the turbine inlet total temperature is 2000° R.

Runs have been made with turbine inlet total pressures of 20, 30, 40, and 45 inches of mercury absolute for a constant total-pressure ratio across the turbine of 2.40, the maximum value that could be obtained. Additional runs have been made with total-pressure ratios of 1.50 and 2.00 at an inlet total pressure of 45 inches of mercury absolute. All runs were made with an inlet total temperature of 800° R over a range of corrected turbine wheel speeds from 40 to 150 percent of the corrected speed at the design point. The turbine efficiencies at these conditions are presented.

TURBINE

For this investigation, the turbine used was obtained from the 19XB-1 jet-propulsion engine (W.E. 000031). The parts consisted of the turbine rotor assembly with bearings and bearing supports,

the turbine nozzle assembly, the turbine stationary shroud, and the combustion-chamber casing with spray nozzle ring. The turbine is the prototype for the turbines of the 19XB-2A engines.

The turbine wheel has 54 tapered blades $2\frac{1}{8}$ inches long and has an over-all diameter of $16\frac{1}{8}$ inches. The turbine nozzle consists of 48 nozzle vanes with a flow height of $2\frac{1}{8}$ inches; the vanes are held in position by an inner and an outer shroud band. The nozzle vanes are precision cast and the turbine wheel blades are machined. The surface finishes of each are of high quality for the particular methods of fabrication.

SETUP

For this investigation no burning was done in the combustion chamber and the burner basket in the combustion chamber was replaced by a honeycomb-type flow straightener. (See fig. 1.) An external burner was installed to supply hot gas for the runs. The laboratory combustion-air system supplied pressurized air at the inlet. The hot gases entered the turbine assembly normal to the turbine axis and flowed into the annulus formed by the combustion-chamber casing. After the gases had passed through the flow straightener, the inlet-gas conditions were measured. The turbine discharge section consists of an outer cylindrical shell with an internal diameter the same as that of the turbine wheel stationary shroud and an inner conical piece 30 inches long, which has a base diameter the same as the root diameter of the turbine wheel. The laboratory low-pressure exhaust system was used to set turbine back pressures.

Power from the turbine is absorbed by an electrical eddy-current-type absorption dynamometer.

MEASUREMENTS

Air-flow measurements were made with a standard A.S.M.E. thin-plate orifice submerged in the 12-inch combustion-air duct upstream of the hot-gas producer.

The turbine inlet total temperatures were measured 6 inches in front of the nozzle section by means of four, quadruple-shielded, chromel-alumel thermocouples equally spaced around the annular combustion chamber midway between the inner and outer casings. The

temperature measurements were subject to no serious radiation effects because the thermocouples were sufficiently removed from the flame region.

The static pressures at the inlet to the turbine were measured by four static-pressure taps in the outer shell of the combustion chamber in the same plane as that selected for inlet-temperature measurement. These taps were located midway between each of the temperature probes. The arithmetic average of these four pressures was used as the inlet static pressure. For operating purposes a total-pressure reading was obtained from a total-pressure probe located in the combustion-chamber casing.

Turbine discharge static pressures were measured by means of six static-pressure taps located in a plane normal to the turbine axis and $2\frac{1}{4}$ inches from the discharge side of the turbine wheel. Three of the taps were installed in the outer cylindrical wall at 120° intervals and three in the inner conical piece at the same angular position as the outer wall taps. An arithmetic average of these six pressures was taken as representative of the turbine discharge static pressure.

Turbine rotational speeds were measured with a chronometric tachometer driven by an electric generator directly geared to the dynamometer rotor. The quantity of fuel used by the hot-gas producer to heat the inlet air was measured with a calibrated rotameter. Dynamometer torque measurements were made with an NACA balanced-diaphragm torque indicator. (See reference 1.)

CALCULATIONS

The calculations were made according to the method in reference 2 with the exception that the pressure ratio across the turbine and the theoretical jet speed were based on the discharge total pressure instead of the discharge static pressure. The inlet total pressure was calculated as in reference 2 and the discharge total pressure was obtained by computing the axial component of the velocity of the discharge gases V_a, using equation (9) in reference 3, and adding the corresponding velocity pressure to the measured discharge static pressure.

RESULTS

The data for this investigation are presented in the form of plots of turbine efficiency η against blade-jet speed ratio U/V for various inlet total pressures and total-pressure ratios at a constant total inlet temperature of 800° R. The pertinent results are presented in figures 2 and 3. The peak efficiency was obtained at a blade-jet speed ratio of 0.525 to 0.575 for all runs. The maximum efficiency obtained in these runs is 0.765 at an inlet pressure of 45 inches of mercury absolute and a pressure ratio of 2.0. The variation in peak efficiency with inlet pressures and pressure ratios is of small magnitude for the conditions investigated.

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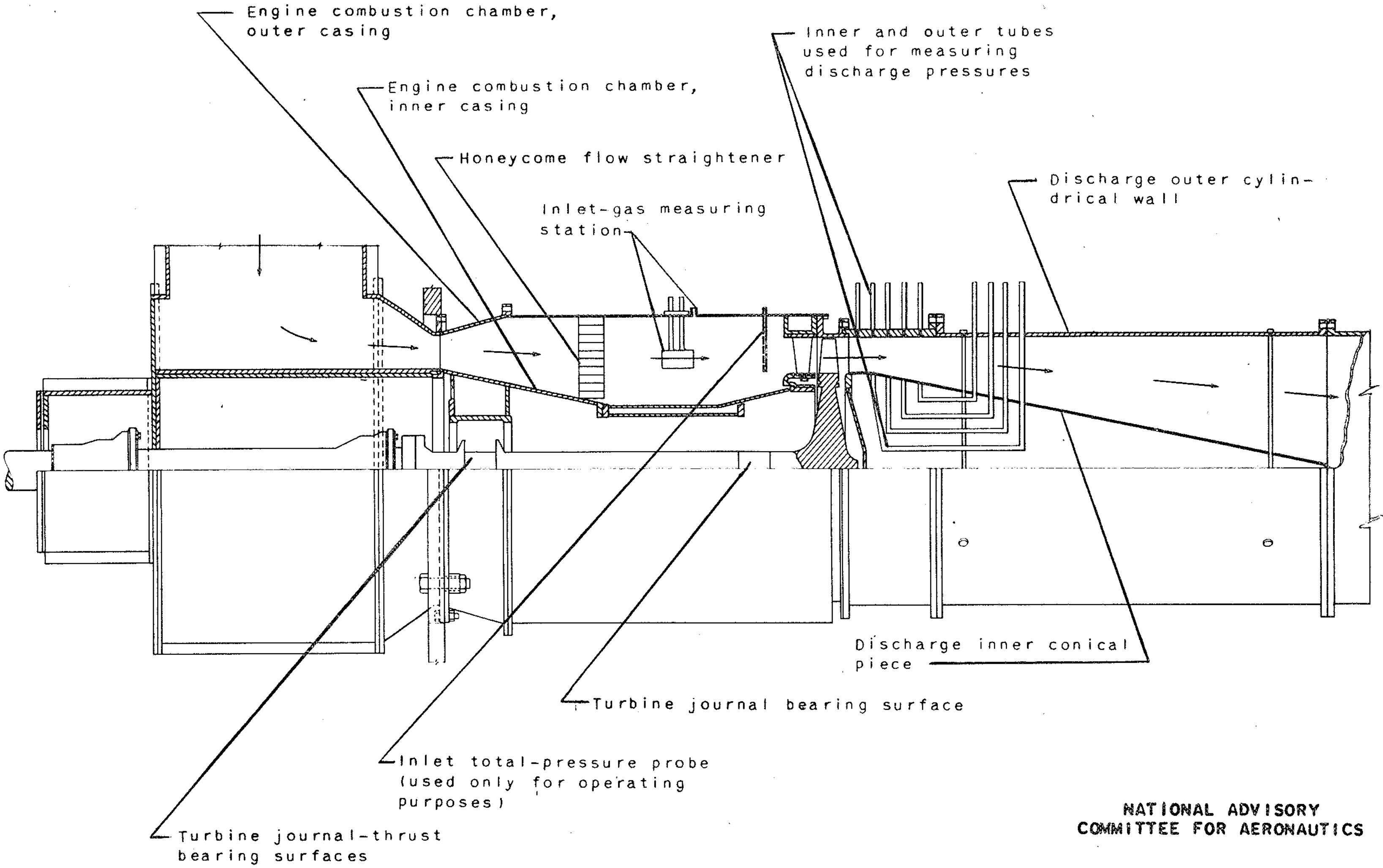

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Figure 1. - Setup used for investigation of the effect of pressure ratio and inlet pressure on performance of 19XB-2A gas turbine.

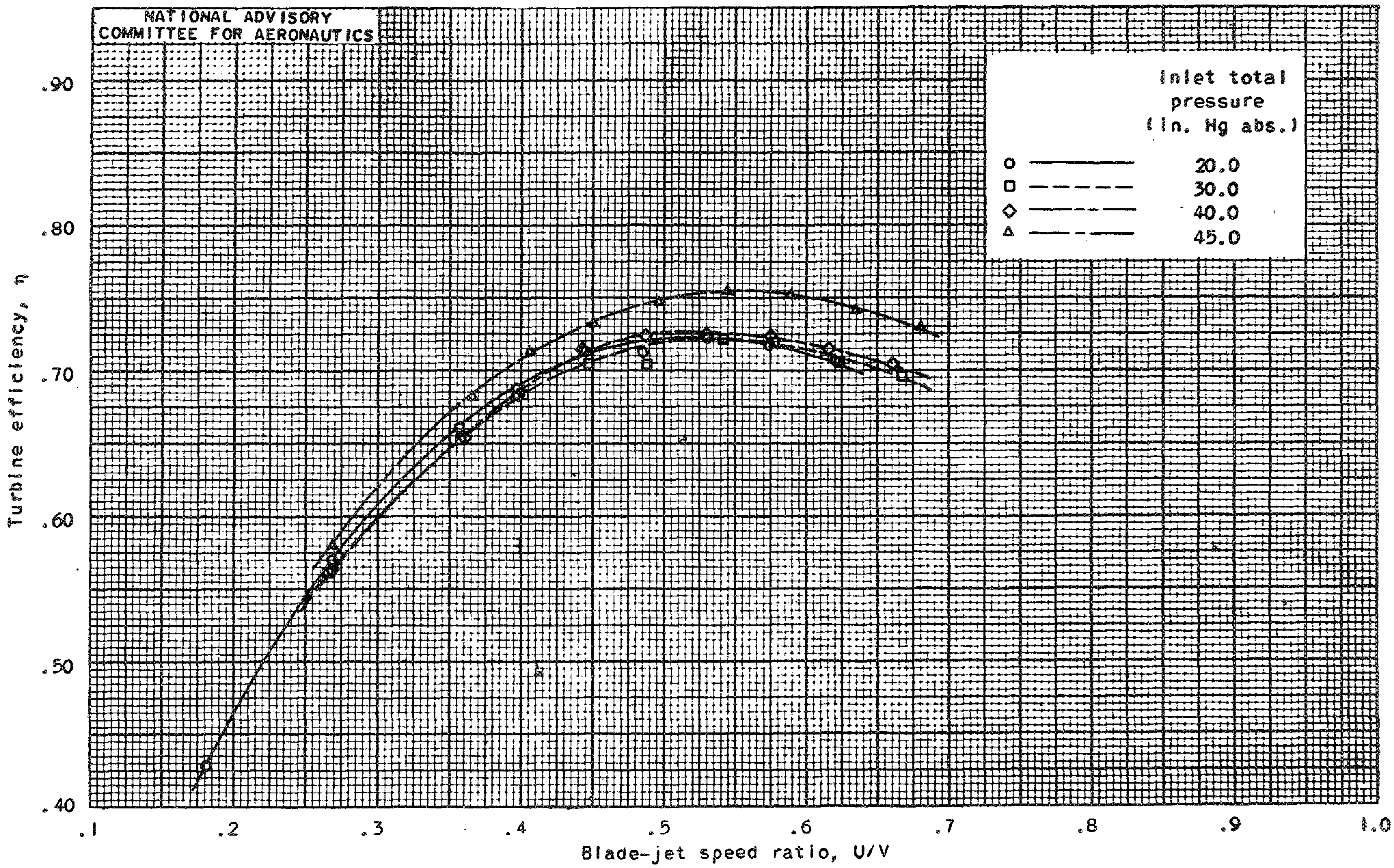

Figure 2. - Variation of turbine efficiency with blade-jet speed ratio for several values of inlet total pressures at a total-pressure ratio of 2.40 and an inlet total temperature of 800° R for the 19XB-2A gas turbine.

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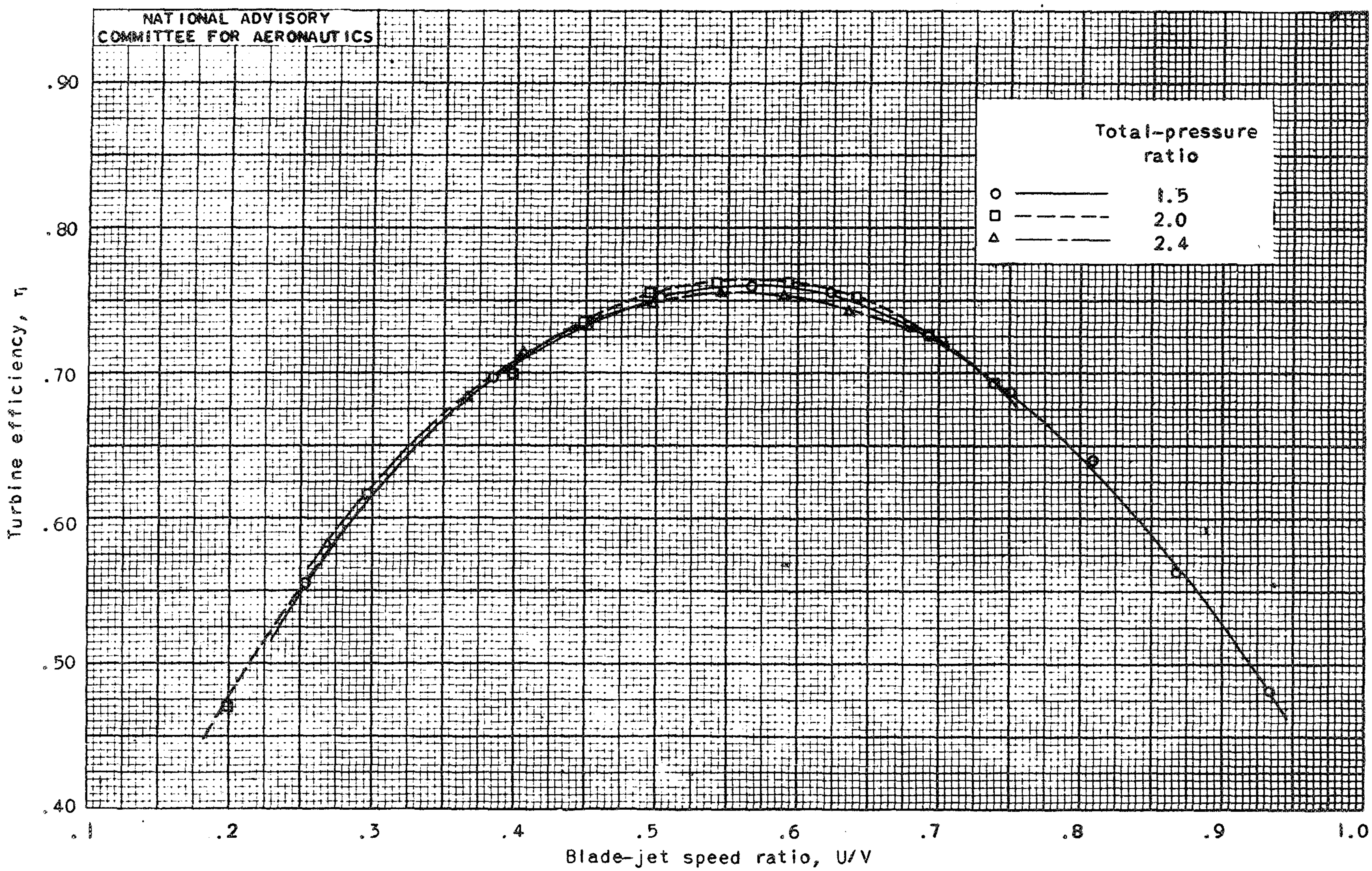

Figure 3. - Variation of turbine efficiency with blade-jet speed ratio for several values of total-pressure ratio at an inlet pressure of 45.0 inches mercury absolute and an inlet total temperature of 800° R for the 19XB-2A gas turbine.

Fig. 3